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ABSTRACT

China will suffer into the future from a shortage of computer professionals. With 75% of her population engaged in agriculture, she has only about 100,000 computer professionals, which is less than can be found within a healthy radius of Stanford University. There are 97 "key universities," but only 10 or 15 stand at the top as the nation's best; students in higher education comprise .001% of the total population and .007% of the total student population. Despite a general awareness of the country's pressing needs, China is not moving and changing fast enough to modernize and catch up with advanced countries. Although computer centers independent of the computer science department have been set up at a selected number of universities, all of the terminal work stations are located within the computer center building, which tends to inhibit rapid dissemination of the technology. Critical campus needs include library automation, updated classification coding systems, and the development and use of a management information system. Until China's academic communities become familiar with and comfortable with online information technology, it will not penetrate to other sectors of China's economy and society. China wants to modernize by the year 2000 to a level of the advanced countries in the 1980s. To begin to catch up or make relative progress, she must move faster than the technology. (DJR)

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John H. Maier

Computer Science Education in the People's Republic of China

This article is based on Mr. Maier's year-long experience of lecturing on computer science in China by invitation of the Ministry of Education of the People's Republic of China in a special program for recently graduated Chinese scientists, and on his visits to computer centers and computer science departments in 16 key universities. He has also worked for the Bank of America and the U.S. Agency for International Development. A version of this article will also appear in IEEE *Computer*.

Introduction

Frequently when we look at a network map or telecommunications topology of Asia, we find that China is not included or at best is only sparsely represented. This is true of airline reservations systems, banking networks, computer research networks, voice pathways, and other topologies. That is why China wants to modernize, but for China to do so requires a broad foundation and capability in computer science—something acquired much earlier in the West.

The U.S. Experience

Prior to the 1960s, computer-related education in the United States was heavily oriented to mathematics and engineering usage and principally directed toward people who had direct design and working relationships with the machines. However, the National Academy of Sciences' 1966 report on "Digital Computer Needs in Universities and Colleges" and the President's Science Advisory Committee's 1967 report on "Computers in Higher Education" both resulted in specific broad national curriculum recommendations opening up computer science to the academic community. By 1977, a national survey of approximately 3,000 U.S. educational institutions showed that more than 100 offered the Ph.D. in computer science—and there were more than 1,500 computer-related degree granting programs with more than 130,000 students (80,000 of them undergraduates) specializing in computer science nationally. In 1982, a review of the nation's needs in computer science education by the chairman of 80 U.S.

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computer science departments predicted there would be an acute shortage of computer science professionals by the 1990s.

China's Computer Education Crisis

The total number of computer professionals, estimated at about 100,000 in 1984, is less than can be found within a healthy radius of Stanford University. China's top leaders, including the minister for education, the president of the Chinese Academy of Sciences, and members of the State Council, realize the urgent need to join the automation revolution. Members of the Chinese Academy of Sciences have begun to understand the vision of the electronically-connected global village.[1] In a lecture at Fudan University in Shanghai, President Reagan specifically mentioned a new U.S. computer being installed there.[2] Yet despite a general awareness of the country's pressing needs in computer-related technology, China is not moving and changing fast enough to modernize and catch up with advanced countries in a technology that is undergoing generational changes every five years.[3]

With more than a billion people, 75 percent of them engaged in agriculture, China is decentralizing large portions of the previously centrally planned economy and opening up market forces. China's needs are unique to China, but there can be no doubt that computer technology and related communications technologies are central to her hopes for modernization.

An Overview of China's Educational System

There are more than 800 universities and colleges, 100,000 secondary schools, and 860,000 primary schools in China, with one million, 40 million, and 136 million students respectively. There are 97 "key universities," so designated by the ministry of education; of these, 10 or 15 stand at the top as the nation's best higher education institutions. Students in higher education comprise .001 percent of the total population and .007 percent of the total student population. Entrance to most universities is by examination. Tuition, lodging, and medical care are free of charge; students pay only for their food and textbooks. After the 10-year educational chaos of the Cultural Revolution, Chinese higher education institutions began to grant baccalaureate and advanced degrees in 1981, and since that time the institutions have awarded a total of 320,000 bachelor's degrees, 15,000 master's degrees, and 18 doctorates.

Open universities provide high level adult education on television, and correspondence colleges, night universities, and factories offer programs for workers and others. More than a million people study in their spare time through these programs.

Campus Automation in China

At best, campus automation in China is only beginning. University officials are going through the same painful processes that U.S. administrators experienced in the 1960s as they began to struggle with the appropriate role for this technology on campus.

Recently, computer centers independent of the computer science department and reporting directly to the university president have been set up at a selected number of key Chinese universities. This is similar to campus organization in the U.S.[4] The phenomenon occurred when it was realized that computer technology was to be in fact a campus-wide resource. Management of the resource, however, requires that the campus be educated as to its potential. As presently configured on campuses in China—where new, fairly large-scale machines with some 60 or 70 remote terminals have recently been installed—all of the terminal work stations have been tightly located within the computer center building rather than being dispersed to potential user departments. This again was the configuration experience of the U.S. in the 1960s and early 1970s. This type of management of the resource generally tends to inhibit rapid infusion of the technology into the infrastructure of the various departmental facilities and student populations.

China is still quite a distance from the current U.S. environment in which campus-wide local area networks deliver computer services directly to user populations within their work environments. Now is the time for campus planners to design for this goal and target CPU workloads at departmental locations. The key universities are undergoing substantial building expansion programs—a healthy sign. But they may be constructing new buildings in form rather than in substance unless the campus environment being designed considers future technological needs, an important one being campus-wide delivery of computer services.

Automation of Chinese Libraries

A critical campus need is library automation, a seminal information technology accomplishment. Libraries are the heart, soul, and key resource of any learning and knowledge production community. This has been true since the time of Socrates[5] and the Hanlin Academy of the Han Dynasty, but in the 20th century the explosive growth in volume of available information mandates computerization of important libraries, something that occurred in the U.S. in the mid-1970s. It should be noted that an important benefit of automation is that it necessitates rationalization and rigorous systemization, a healthy process that would be beneficial to reforming and modernizing China's library systems. For China it will be like birth into a new era.

China's difficulties with automation of Chinese characters have been essentially solved, with many viable systems (in varying hardware and software environments) now available. In fact, Chinese character (ideograph) input and output methodologies can differ according to circumstances, needs, and levels of skill of user populations. The main focus should be on internal standardized systemic binary representation so that there is compatibility in multi-system interfaces, including with western products. The technology is available. Choice is now the appropriate action.

China's library classification coding system is dated (lacking, for example, categories for many newer technologies in computer science) and differs from other

The People's Republic of China, home to almost one-quarter of the world's population, has an estimated 100,000 computer professionals, less than can be found within a healthy radius of Stanford University.

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widely used systems such as the Library of Congress system and the Dewey Decimal system.[6] It is possible, however, to work around these circumstances with a software system design that is flexible for classification system growth and expansion and for cross-reference tables into other coding classifications. China's knowledge base contained in her libraries is in part integral to general world scientific knowledge, but it also contains highly specialized categories of knowledge unique to China. To date, however, only one small, limited, prototype library automation project in China has come up.

The point is that the technology now makes it feasible for China to automate her important libraries—but until this watershed is passed, China's researchers, scientists, students, and general faculty will be seriously handicapped. Further, until China's academic communities become familiar with and comfortable with on-line information technology, it will not penetrate to other sectors of China's economy and society.

Campus MIS

Another area of campus-related automation that is only beginning in China is Management Information Systems (MIS), specifically of university populations and resources. I have encountered only one campus on which development of such a system was underway. Systems now taken for granted on U.S. campuses—student registration, course lists, grades, alumni lists, transcripts, budget, etc.—are applications which combine to form a campus MIS that no Chinese campus, to the best of my knowledge, has yet implemented. Such a system would be an excellent design project for one of China's new management science departments to undertake in cooperation with the computer science department. A problem on campuses and elsewhere is the rigid structure of and lack of cooperation between working units. A lesson that has to be learned is that computerization cuts across these lines and breaks down walls. Implementation of a campus MIS would result in a first for China, would be a model, and perhaps could be replicated elsewhere on an inter-university consultancy basis, thus saving the country's universities important applications development time. Finally, automation will not occur easily elsewhere in Chinese society until campuses get their own houses in order.

Computer Science Education

China's activities in computer technology date from 1958 when the Institute of Computing Technology under the Chinese Academy of Sciences produced a first-generation vacuum tube computer capable of 1,000 operations/second. Today, China has successfully built a 100 million operations/second vector array

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processor, the "Galaxy" or "Yinhe," making China one of the few countries in the world that can produce "super computers." The country has also placed a functioning communications satellite into geostationary orbit. But China has not yet matched these salient accomplishments— which required intensive research and development coordination—with a breadth and depth of computer science activity in her various social and economic infrastructures.

It could be that there are now promising beginnings for producing a new generation of broadly trained computer science professionals. Thousands of Chinese students, not all in computer science, are studying in the U.S. They will return to China more familiar, to one degree or another, with the pervasive computer systems they have encountered on U.S. campuses. The number of these professionals being trained, however, is seriously insufficient for China's future needs.

The universities most frequently mentioned in connection with computer science are Qinghua, Jilin, Beijing, Nanjing, Fudan, Shanghai Jiaotong, and Xian Jiaotong. Computer science departments are rapidly emerging at other universities. One is at Hunan University, closely related to the China National Defense University where the "Galaxy" was developed.[7] Some schools have extended strength in such allied departments as physics, mathematics, astronomy, space sciences, engineering, and other sciences. There are about 15 universities invariably considered to be at the top in computer science; some have breadth, some have very specific specialities. Many more schools are planning to upgrade their computer resources with hardware acquisitions, expansion of curriculum, faculty training and cross-fertilization, and increased student recruitment. It seems, however, that as first priority in the near term China should concentrate on building more strength and reforming current computer science departments where encouraging work is occurring.[8]

[This article does not attempt to deal with the computer related institutes of the Chinese Academy of Sciences[9] or other computer activities such as those in ministries[10] or provincial governments.]

A picture of China's top-level computer science departments has not fully emerged, but it is possible to discern both encouraging developments and problem areas. The latter include "danwei mentality" or lack of cooperation between working units, inbreeding of faculty with graduates, and a concomitant absence of inter-university cross-fertilization; excessive faculty concentration on theoretical activities with slow growth in applications work; insufficient attention to and effort in interdisciplinary research and applications; a narrow range of available texts in Chinese[11]; lack of openness of department curriculum[12]; insufficient importance given to the role of software engineering and software economics; and no well-defined vision of where the discipline of computer science should lead in China in the future. While these comments do not apply in all cases, they reflect some consistent general impressions.

Encouraging developments include emergence of AI studies[13], a healthy interest in activities of colleagues elsewhere in the world and especially in the U.S., strong enthusiasm of students (which should not be underemphasized and might indicate in Kuhnian terms that the prior generation is on the twilight side of a new paradigm for China now unfolding), relative growth of undergraduate populations (top schools now have computer science department enrollments ranging from 200 to 500 students), beginning graduate programs (although only one or two departments in China can confer the doctoral degree in computer science), some curricula that are excellent (although they do not match the strength of top U.S. schools), growth and development in journal publications, beginnings of specific real applications and substantive student projects, formation of user groups, and a broad awareness of microprocessor technology. Also, some computer science libraries are fairly well stocked with Western and other non-Asian journals and books, although journals invariably lag by six months; the list of titles is thorough, but students are not always allowed access.

Lecturing in China

A special adjunct faculty professorship in computer science was established at Sun Yat-sen University in Guangzhou during the 1984-85 academic year. It was created in the belief that computer science was the one discipline common to all sciences and prerequisite to successful postgraduate studies in the U.S.

Courses were devised to accommodate the prior computer science experience and education of the students. Testing based on ability to define selected terminology[14] in computer science plus as inventory of experience with hardware and software revealed that approximately 70 percent of the students had little or no prior experience, 25 percent had some limited programming experience, and five percent had some advanced scientific computer-related experience. The courses devised were, for the first group, "A General Introduction to Computer Science;" for the second, "A Survey of High Level Procedure Oriented Languages;" and for the third, a seminar on "Advanced Computer Applications." Topics in the latter seminar included computer performance measurement, a state of the art overview of computer technology, procedure oriented languages, computer science education in the U.S., fifth generation goals, voice recognition systems, space orbit control software, natural language processing, expert systems, and others. A central feature of the program was to prepare students for the pervasive presence of computer technology in the U.S. It is worth noting that some of the course content was not available elsewhere on campus, largely because the prior generation of educators in China does not have the background to present it.

The students, who were young, recent university graduates, were generally enthusiastic, receptive to ideas for computer utilization and applications within their disciplines, eager for hands-on experience, and open to creating opportunities to spread the science into new areas useful for China.

The opinions stated herein are those of the author and do not necessarily represent the views of the Pacific Telecommunications Council or its members.

Even if the top 15 computer science departments were to enroll 400 students each and 100 other schools, 100 students each on a continuous level for the next decade, there would be only 35,000 additional computer science professionals by 1995.

Some Recommendations

If I had a mandate to reorganize and improve computer science education in China, my recommendations would include these:

- Development of national computer science curriculum guidelines, such as those developed in the U.S. in the late 1960s;
- Regular, mandatory periodic acceptance by faculty of teaching and research positions at other than home institutions;
- Higher priority in the national budget for computer science departments including monetary incentives for faculty;
- Design of specific courses for the non-computer science campus population;
- Open publication of department curriculum;
- Opening of computer science departmental courses to non-departmental students on a consent basis;
- Involvement of students in real projects such as development of campus MIS;
- Articulation by computer science departments of quantitative and qualitative five-year goals that involve a vision of the campus of the future and of China's needs; and
- Establishment of visiting professorships for faculty from abroad.

Additionally, in a technology in which there is an acute shortage of manpower in China, faculty members and even students should be encouraged to serve as consultants to organizations outside the university. This would be good "theory and practice" in China.

Summary

Like the United States, China will suffer into the future from a shortage of computer professionals, but China's shortfall will be greater if present educational levels continue. By its own count, China has approximately 100,000 computer professionals and there is no classification of their skill levels. Even if the top 15 computer science departments were to enroll 400 students each and 100 other schools 100 students each on a continuous level for the next decade, there would be only 35,000 additional computer science professionals by 1995. The U.S. is currently graduating one computer science student for every 4,000 in the population; at the above rate, China would be graduating one for every 250,000 of its people.

As one example of technological lag, China has not yet implemented her first national digital network, the difficulty being the quality of terrestrial telephone lines in China. In the U.S., we take for granted a plethora of networks, public and private, and we do not hesitate when we hook up a modem to the nearest telephone instrument. China is importing technology, hardware for example, and negotiating with the U.S. for an advanced geostationary satellite. This may immediately solve China's national needs for reliable data communications and Chinese computer scientists may then get to work on a long list of applications waiting to be implemented. But everything takes time.

China wants to modernize by the year 2000—the year that China hosts the Olympics—to a level of the advanced countries of the 1980s. If we consider planning in three phases—to catch up with technology, to stay abreast of technology, and a move ahead of technology—China would be in the "catch up" phase of a very dynamic, rapidly moving technology. She must move as fast as the technology just to maintain her current relative position. To begin to catch up or make relative progress, she must move faster than the technology. Computer science is a key technology, key perhaps to all the sciences today; realization of its importance will only grow in the future.

Possibly a national computer conference (similar to China's 1978 national science and technology conference), would suffice to articulate and coordinate China's specific goals and priorities, provide a needed stimulus, and result in a commitment of resources. Such a conference should carry the blessing of the State Council and involve computer science and other departmental chairmen, university presidents, and leaders from the ministry of education and the Chinese Academy of Sciences.

If there is doubt about the importance of computer science to the aspirations of China to modernize, let me quote a Tang Dynasty poet:[15]

> *The woods are black and a wind assails the grasses*
> *Yet the general tries night archery—*
> *And next morning he finds his white plumed arrow*
> *Pointed deep in the hard rock.*

Postscript

The United States technology export guidelines for China are still atavistic, are seriously hampering China's modernization efforts, and are not appropriate to the relationship between China and the U.S.[16] With her massive inventory of hardware and software and well-developed systems, the United States should not feel any threat from China's relatively modest efforts and needs to develop systems within her society and economy.

John Maier close to a radio telescope on Purple Mountain in Nanjing.

[1] *The Abrupt Rise of the New Technology Revolution* (Xin Jishu Geming De Jeuqi) Chinese Academy of Science Publications, 1984. Also, note the translation into Chinese of John Naisbitt, *Megatrends: Ten Directions Transforming Our Lives* (Da Qu Shi) China Social Science Publications, Beijing, 1984.

[2] Between 15 and 30 Chinese universities are receiving Honeywell upper medium scale machines as a result of a World Bank China Universities Automation Loan, valued at several hundred million dollars. Some of the universities are Beijing, Qinghua, Jilin, Fudan, Shanghai Jiaotong, Zhehiang, Nanjing, Huazhong, Xian Jiaotong, Tianjin, the China University of Science and Technology, and Dalian. What we are seeing is that Chinese campuses have very recently begun acquiring the necessary inventory of hardware for work to begin for China to build the systems she needs and to train a new generation of computer scientists, largely on imported Western hardware.

[3] The concurrence of Chinese social scientists with Western counterparts about the rate of change is evident in *A Dictionary of the World's New Technology Revolution* (Shi Jie Xin Jishu Geming) "Modernization Information Collection," Popular Science Publishers, Beijing, 1984.

[4] In an informal survey of newly installed U.S. hardware at universities and research institutes in all parts of China, I counted several hundred, including 30 or so Honeywell DPS 7s and 6s, around 10 Data General MV 6000s, about 15 Perkin Elmer 32XXs, around 35 IBM-compatible Fujitsus, at least 35 IBM 43XXs, Some VAXs, and numerous Wangs.

[5] "Socrates," interestingly, is the name of Stanford University's campus-wide library automation and information retrieval system. It has always been this author's desire to sit at his desk and be able to access any library in the world, regardless of language. It should be noted that in China national research centers and libraries have high priority, but accomplishments have been slow.

[6] At Beijing Library, which is the national library of China, an automation project on a Fujitsu is making progress, and cooperation with the U.S. Library of Congress has been established so that Beijing Library will be using MARC format computer records for interlibrary exchanges. China's 1978 national science and technology conference, attended by Deng Xiaoping, gave top priority nationally to library automation. Progress has been very slow.

[7] As one example of a curriculum, Hunan University offers courses in discrete math, digital logic, fundamental project design, data structures, complier principles, operating systems, microcomputer applications, DBMS structures, methods of design and analysis, microcomputer operating systems, computer systems construction, image processing, special engineering, LISP, technical interface LSI, PASCAL, C, FORTRAN, networks, computability, CAD, AI, expert systems, software engineering, Fast Fourier Transforms, UNIX operating system, control systems, Chinese information systems, and others.

[8] A sampling of work being done in some Chinese universities would include:

BEIJING—research in laser photocomposition for Chinese character texts, image processing, data acquisition, DBMS development.

NANJING—programming language design (XCY-2), distributed system software (distributed C language and distributed dBASE II), Chinese wordprocessing software, library automation, development of an ADA compiler.

HUAZHONG—campus automation.

XIAN JIAOTONG—development of an Apple II LISP compiler.

PEOPLE'S UNIVERSITY OF CHINA—development of a relational DBMS on an HP 3000, Chinese information processing systems, development of a system for national economic and statistical data.

WUHAN—library automation, formation of an interdisciplinary AI group.

QINGHUA—development of applications software packages for micro and minicomputers, software product testing tools.

HUNAN—final product implementation of PDP 11/23 Chinese word processing and text editing, conversion of system to IBM-PC (in PASCAL), communication of system with IBM 43XX.

SHANGHAI JIAOTONG—software for financial analysis, graphics for micro and minicomputers.

JILIN—research and development of expert systems, AI work.

Also of interest: at the Beijing Institute of Computing Technology of the Chinese Academy of Sciences, work was in progress in development of LISP, C, and PROLOG compilers on the Chinese BCM-3 machine.

[9] Computer science related institutes directly under the Chinese Academy of Sciences might include the institutes of mathematics, applied mathematics, systematic science, computing technology, automation, remote sensing application, the academy's computer center, and the space and technology center; also the Shanghai Institute of Brain Study, Hefei Institute of Intelligent Machinery, Chengdu Institute of Computer Applications, Shenyang Institute of Computing Technology, Shenyang Institute of Semiconductors, and Beijing Institute of Electrical Engineering.

[10] Minimally, ministries concerned would include those for posts and telecommunications, national defense, and electronic industry. And then at the provincial level, for example, ten recognized provincial computer centers have been established with IBM 43XX machines purchased under a UN loan for China's 1982 census, the first fully automated national census in China.

[11] In visiting many bookstores in Guangzhou, Shanghai, Nanjing, Wuhan, Changsha, and Beijing, I found that at best not more than 100-200 titles on computer science in Chinese were available, and many were recent translations from English sources.

[12] Universities do not publish campus-wide curriculum catalogs, and departments tend to hold tightly their course listings, making it difficult, for example, for a biology student to take a computer science course.

[13] The Chinese are researching in natural language processing, voice systems, knowledge representation, visual systems, robotics, etc. In China, Jilin University, where Professor Wang Xianghao is noted and empowered to confer the Ph.D., is always mentioned first for AI work. In November of 1984, China sent a delegation to Japan's Fifth Generation conference. An AI journal, *AI World*, is published by Xinhua Communications, and Chinese researchers are publishing abroad in, for example, the winter 1983 issue of *The AI Magazine*. An example of a knowledge system is a Chinese traditional medicine expert system now in use.

[14] The "screening" test included a list of words requiring one sentence definitions (science, system, information technology, operating system, network, innovation, bit, word length, application, modeling, interface, FORTRAN, computer science, feasibility, analog, algorithm, data, loop, expert system, protocol, I/O, CPU, microprogram, and ASCII), a hardware experience checklist, and a written description of any application program the student had ever written, and finally a question on why the student might find computer science interesting.

[15] Li Bai

[16] In fact, according to a recent report by the U.S. National Academy of Sciences, "America's ties to China added importance given the United States' rapidly increasing economic, intellectual, and strategic stake in the entire Pacific region." See *China Exchange News*, Committee on Scholarly Communications with the People's Republic of China, March 1986, p.4.